

Reverse osmosis of a biomass leachate for water and materials recovery

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Water washing or leaching of biomass, especially of straws and other grasses, has been demonstrated to reduce the fouling and slagging characteristics and greatly improve combustion properties by removing large fractions of alkali and chloride [1-5]. In some instances the leaching can be carried out in the field by leaving the biomass exposed to precipitation and then harvesting once dry. This technique, although generally inexpensive, is at best poorly controlled and suffers from weather variability and the risk of contamination of fuel with soil, organic matter loss and degradation of fuel quality, and unpredictable scheduling of cultural operations for subsequent crops. An alternate technique is to leach biomass in controlled operations at the industrial site. In the latter case, the fuel quality can be improved relative to field leaching, but fuel dewatering and drying become more difficult and expensive, and a large volume of leachate is produced. Where a biomass facility is suitably located, leachate may be disposed of through land application, thereby returning valuable nutrients to the field. Leachate disposal by this method is likely to be carefully regulated, and without concentration may considerably increase the facility water consumption. Concentration of leachate offers the potential to recycle clean water to the process while enhancing the opportunity for materials recovery from the concentrated stream or reducing the cost of disposal.

Leachate from rice straw was concentrated using a pilot membrane unit to evaluate system performance and estimate concentration costs. A single stage membrane testing unit employing a spiral membrane module (Desalination Systems, Inc., model SH2540) was used in two experiments. The module incorporates a low pressure thin film composite membrane intended for brackish water demineralization. The module contained a surface of 2.4 m², with a rated flow of 95 L h⁻¹ on 1000 mg L⁻¹ NaCl at 1.1 MPa pressure, 25°C, and 25% permeate recovery. The permeate flux under the rated conditions is 40 L m⁻² h⁻¹ with a salt rejection of 96%.

Whole rice straw was leached in two batches of 10 kg air-dried (9.4 kg dry basis) material each. Both batches were soaked fully submerged for 24 h at room temperature without agitation. The first batch was soaked in 325 L of deionized water, the second in 350 L. Leachate was drained from each batch and used in the two membrane concentration experiments. Straw from the first batch was subsequently soaked another 24 h in 378 L deionized water to evaluate the extent of leaching occurring during the first soak. 83% of K was leached in the first soak, increasing to 90% for the second. Cl removal was 99% after the first soak. Total ash was reduced about 16% in both cases.

The first concentration trial started with 100 L of leachate from the first straw batch. Flow rate along the membrane module was 22 L min⁻¹ corresponding to the maximum capacity of the feed pump used. Inlet pressure was maintained at 2 MPa, and the pressure at the outlet remained stable also at 2 MPa. Six sets of readings were collected at six recovery levels corresponding to roughly 20 L increments of permeate drained between readings. Permeate and retentate were returned to the feed tank during the first 5 min of operation to allow steady operation at each recovery level before sampling. Permeate flux at zero recovery was 56 L m⁻² h⁻¹, leveling at 50 L m⁻² h⁻¹ between 20 and 80% recovery before declining to 32 L m⁻² h⁻¹ at 95% recovery. Electrical

conductivity (EC) of permeate increased from $95 \mu\text{S cm}^{-1}$ at the start to $1350 \mu\text{S cm}^{-1}$ at the end. EC of retentate increased from $2,450 \mu\text{S cm}^{-1}$ to $21,500 \mu\text{S cm}^{-1}$. Between zero and 95% permeate recovery, EC rejection by the membrane decreased from 96.1% to 93.7%. Chemical oxygen demand (COD) of permeate varied between 72 and 261 mg L^{-1} , increasing at recoveries above 60%. COD of retentate increased from an initial 1,660 to $15,500 \text{ mg L}^{-1}$ at the highest recovery.

The second concentration trial used a total of 250 L of leachate. For this test, the membrane feed tank was kept full at 100 L until the first 150 L were used. Feed volume then decreased until the full 250 L had been processed. All other operating conditions were the same as the first trial. Temperature slowly increased from 28 to 38°C through most of the run, increasing rapidly to above 50°C at the end. Permeate flux at the beginning was $41 \text{ L m}^{-2} \text{ h}^{-1}$. Flux declined in a manner similar to the first trial until near the end of the test the flux dropped to less than $4 \text{ L m}^{-2} \text{ h}^{-1}$. At the end of the test, EC in the retentate had increased to $50,000 \mu\text{S cm}^{-1}$. The low final flux is due to high osmotic pressure and fouling of the membrane. COD in retentate increased from 1300 to $35,800 \text{ mg L}^{-1}$, but maximum COD in permeate was 42 mg L^{-1} , achieving 98-99% COD rejection and higher than in the first trial. Retention of all ions except carbonate exceeded 90% prior to the final sample at the highest concentration. A number of sugars and acids were identified in the leachate, most prominent being acetic acid for which the membrane yielded a 95% rejection.

Permeate fluxes at 2 MPa are close to the rated flux, providing ample margin up to the maximum rated module pressure of 4 MPa. Recoveries of 90 to 95% can in general be anticipated. An economic analysis for an RO system treating 1.35 ML d^{-1} of leachate from 135 Mg d^{-1} of straw suggests a treatment cost of $\$588 \text{ ML}^{-1}$. The cost is equivalent to $\$5.88 \text{ Mg}^{-1}$ dry straw [6], adding roughly 20% to the delivered cost of straw at regionally located biomass power plants. The cost does not include the leaching system that potentially adds another $\$10 - 12 \text{ Mg}^{-1}$ dry straw [6].

References:

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